Acoustics of Speech and Hearing

Lecture 2-2

Fundamental Frequency Analysis

Term Plan

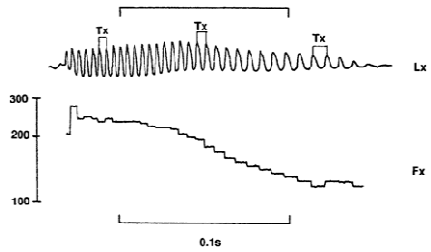
- Source
  - Voice & intonation (Weeks 1-2)
- Filter
  - Steady state (vowels & fricatives) (Weeks 3-4)
  - Dynamic (approximants & stops) (Weeks 5-6)
- Hearing
  - Vowel & consonant perception (Week 7)
  - Loudness, pitch & timbre (Weeks 8-10)

Overview

- Fx Contours
  - Form and function
- Fx Distributions
  - Analysis of central tendency
  - Analysis of range
  - Analysis of regularity
- Normal/Pathological Distributions

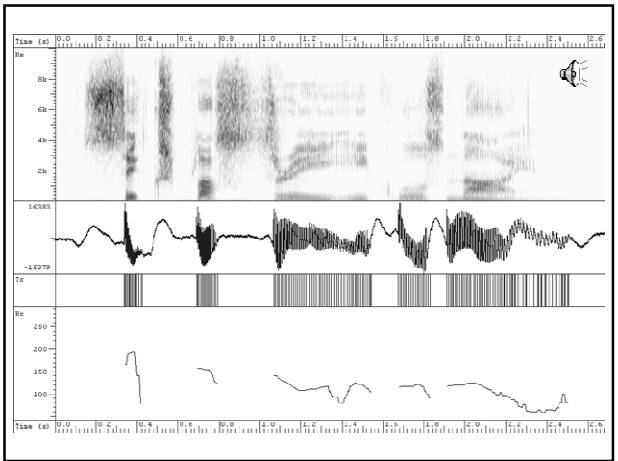
Fx Contours

- Lx → Tx → Fx



Fx contours

- Each rapid closure in Lx easy to find
- Time between successive closures = Tx
- Instantaneous fundamental frequency estimate, Fx = 1/Tx
- Plot Fx against time → Fx contour



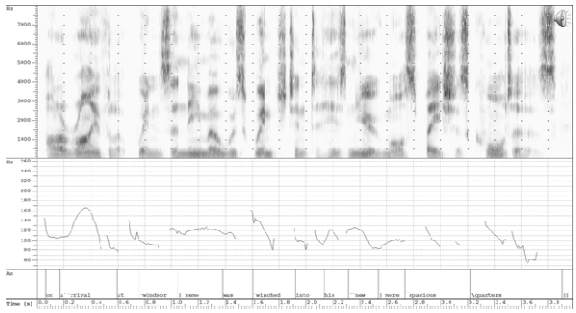
Fx contours

- Characteristics of Fx contour
  - shows how Fx changes through utterance
  - over range of values typical for speaker
  - shows how voicing switches on/off
  - shows regions of irregularity/creaky voice

Intonation

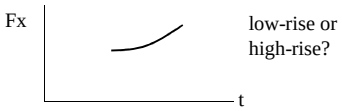
- Prosodic phrasing
  - speech broken up into rhythmic units
- Accented syllables
  - some syllables carry pitch movements
- Nuclear accent
  - one accented syllable dominant
- Nuclear accent types
  - low/high fall, low/high rise, fall-rise, rise-fall

Intonation Transcription



Normalisation

- Cannot interpret Fx contour without knowing Fx range of speaker:

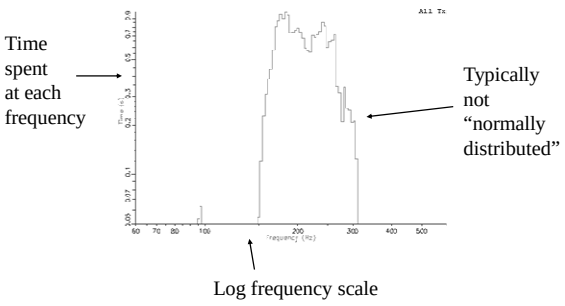


- "low" and "high" need to be related to speaker's range. This is called 'normalisation'

Fx Distributions

- Collect histogram (distribution) of voiced pitch periods
  - for a 2 minute passage (say)
- Plot on axes of
  - logarithmic fundamental frequency (Tx→Fx→log(Fx))
  - time spent at each frequency
- Distribution of Fundamental frequency (Dx)
  - shows typical Fx and typical range of Fx

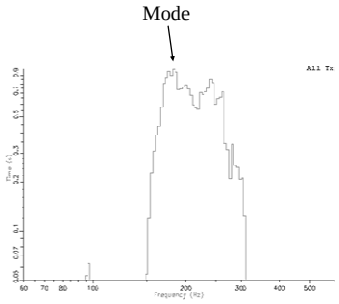
Typical Dx Shape



Dx Central Tendency

- How to find centre of distribution?
  - distribution not normal
  - mean and median seriously affected by asymmetric shape
- Prefer to use modal value
  - most used frequency
  - most 'comfortable' frequency

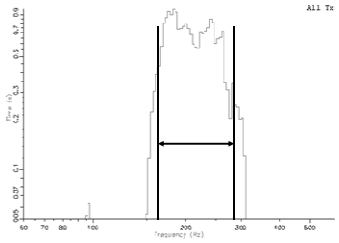
Modal Fx Frequency



Dx Range

- How to find range of distribution?
  - distribution has infrequent values at extremes
  - standard deviation affected by outliers
  - total range set by rare events
- Prefer to use a percentile value
  - e.g. inter-quartile range: includes 50% of all frequencies
  - or distance between 5% and 95% percentiles: **"range used 90% of the time"**

90% Range



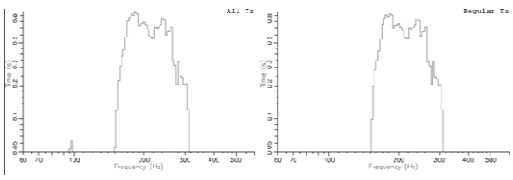
90% range is distance between 5th & 95th percentiles

Dx Regularity

- How to measure degree of regularity?
  - single distribution of all pitch periods doesn't show which come from regions of **regular** and which come from regions of **irregular** voicing
- Decide on criteria for 'regular' voicing
  - e.g. adjacent periods are similar sized
- Compare distribution of all periods (Dx1) with distribution of periods occurring in regular voicing (Dx2)

Compare All Tx with Regular Tx

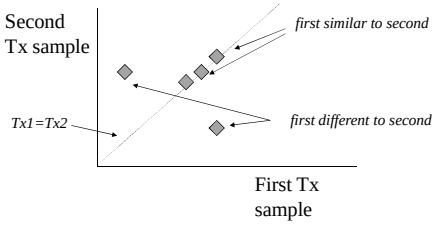
All (Dx1) Regular (Dx2)



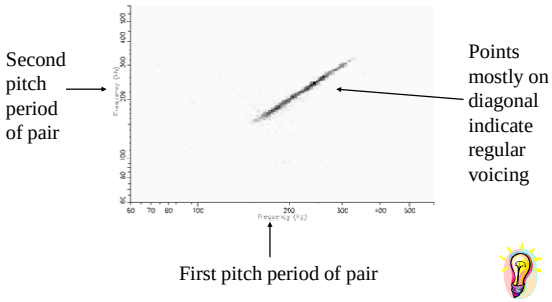
If distributions look the same, then the speech is very regular
Amount of difference measures amount of irregularity

Dx Irregularity

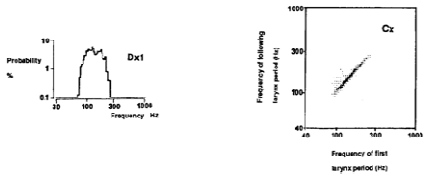
- Alternative to Dx1 & Dx2: scatterplot of adjacent Tx samples (Cx)



Cx Scatterplot

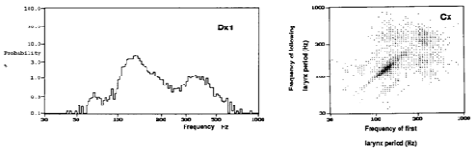


Typical/Pathological Dx



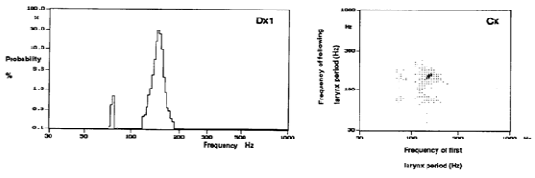
Normal voice

Typical/Pathological Dx



Abnormally large irregularity

Typical/Pathological Dx



Restricted range

Summary

- Fx contours generated from Lx
- How Fx indicates intonation
  - need for normalisation
- Distributions of Fx
- Use of mode and 90% range to characterise distribution
- Measurement of regularity using Dx1 vs. Dx2, and Cx
- Example distributions

Lab Experiment

- Analyse your own recordings
- "Natural world passage"
  - Plot Dx. Measure mode, range, regularity
- "They saw twenty snowmen"
  - Look at implementation of Fx contour in contrast
  - Change statement into a question
- Compare two sentences with Dx mode/range
  - At what percentiles do pre-head/head/nucleus/tail occur?